

ARES I-X: ON THE THRESHOLD OF EXPLORATION

S.R. Davis and B. R. Askins

Ares I-X Mission Management Office, Marshall Space Flight Center
Huntsville, AL

ABSTRACT

Ares I-X, the first flight of the Ares I crew launch vehicle, is less than a year from launch. Ares I-X will test the flight characteristics of Ares I from liftoff to first stage separation and recovery. The flight also will demonstrate the computer hardware and software (avionics) needed to control the vehicle; deploy the parachutes that allow the first stage booster to land in the ocean safely; measure and control how much the rocket rolls during flight; test and measure the effects of first stage separation; and develop and try out new ground handling and rocket stacking procedures in the Vehicle Assembly Building (VAB) and first stage recovery procedures at Kennedy Space Center (KSC) in Florida.

All Ares I-X major elements have completed their critical design reviews, and are nearing final fabrication. The first stage—four-segment solid rocket booster from the Space Shuttle inventory—incorporates new simulated forward structures to match the Ares I five-segment booster. The upper stage, Orion crew module, and launch abort system will comprise simulator hardware that incorporates developmental flight instrumentation for essential data collection during the mission. The upper stage simulator consists of smaller cylindrical segments, which were transported to KSC in fall 2008. The crew module and launch abort system simulator were shipped in December 2008. The first stage hardware, active roll control system (RoCS), and avionics components will be delivered to KSC in 2009.

This paper will provide detailed statuses of the Ares I-X hardware elements as NASA's Constellation Program prepares for this first flight of a new exploration era in the summer of 2009.

INTRODUCTION

Since 2004, the United States has been developing the next generation of crew and cargo launch vehicles to support human exploration beyond Earth orbit. The Ares I crew launch vehicle will launch the Orion crew exploration vehicle to support missions to the International Space Station and to the Moon and beyond. The Ares V cargo launch vehicle will launch the Earth departure stage and Altair lunar lander for missions to the Moon (Figure 1). With the Space Shuttle due to be retired in 2010, Ares I will be the first new vehicle built and flown to provide American human space access in over 40 years.



DISTRIBUTION STATEMENT: Approved for public release; distribution is unlimited.

Figure 1. Ares V (left) and Ares I (right) will provide the launch capabilities for America's space exploration effort.

Like the Apollo program, the Ares launch vehicles will rely upon ground, flight, and orbital testing before sending the Orion crew exploration vehicle into space with astronauts on board. The first flight of Ares I, designated Ares I-X, will closely resemble the Saturn I launch vehicle tests, in that it will be a suborbital development flight test (Figure 2).



Figure 2. Ares I-X (right) follows NASA's tradition of incremental development through flight testing, which has included the Mercury, Gemini, and Saturn programs (left).

As the first flight test of a human-rated vehicle in over 25 years, Ares I-X marks NASA's return to exploration efforts beyond low-Earth orbit. The primary mission objectives include several basic vehicle operations:

- Vehicle integration, assembly, and launch operations
- Staging/separation
- Roll and overall vehicle control
- Aerodynamics and vehicle loads
- First stage entry dynamics for recovery

Much of the data collected during the flight will be used to support the final design of the Ares I crew launch vehicle, which will be evaluated at its critical design review in 2011.

MISSION BACKGROUND

Initial planning for Ares I-X began during the Exploration Systems Architecture Study (ESAS), which formed the baseline designs for Ares I and Ares V. The ESAS team wanted to have at least one development flight of Ares I before the Critical Design Review (CDR), and began gathering requirements for such a flight in 2006.

The Ares I-X demonstration test, scheduled for 2009, gives NASA its first opportunity to gather critical data about the flight dynamics of the integrated launch vehicle stack, understand

how to control its roll during flight, and better characterize the stage separation environment that the upper stage engine will experience during future operational flights. NASA also will begin the process of modifying the launch infrastructure and fine-tuning ground and mission operational scenarios, as NASA transitions from the Shuttle to the Ares/Orion system. Ares I-X will be followed up in 2013 with another suborbital demonstration flight, Ares I-Y, which will be supplemented by at least two orbital verification tests and one automated mission flight before crewed operations begin in 2015.

This important demonstration uses an innovative approach to gathering information prior to the Ares I CDR, which follows in late 2011. The Ares I-X test vehicle will incorporate a mix of flight and mockup hardware, reflecting a configuration similar in mass and weight to the operational vehicle (Figure 3). It will be powered by a four-segment solid rocket motor from the Shuttle inventory, and will be modified to include a fifth, inert segment that makes it approximately the same size and weight as the five-segment motor, which will be available for the next flight test in 2013. The Ares I-X flight profile will closely approximate the flight conditions that the Ares I will experience through Mach 4.5, at an altitude of about 120,000 feet (Figure 4), through maximum dynamic pressure ("Max Q"), which is around 800 pounds per square foot. The flight also will aid the timing of first stage burnout, first stage separation, and upper stage ignition, which should occur around 130 seconds into flight.

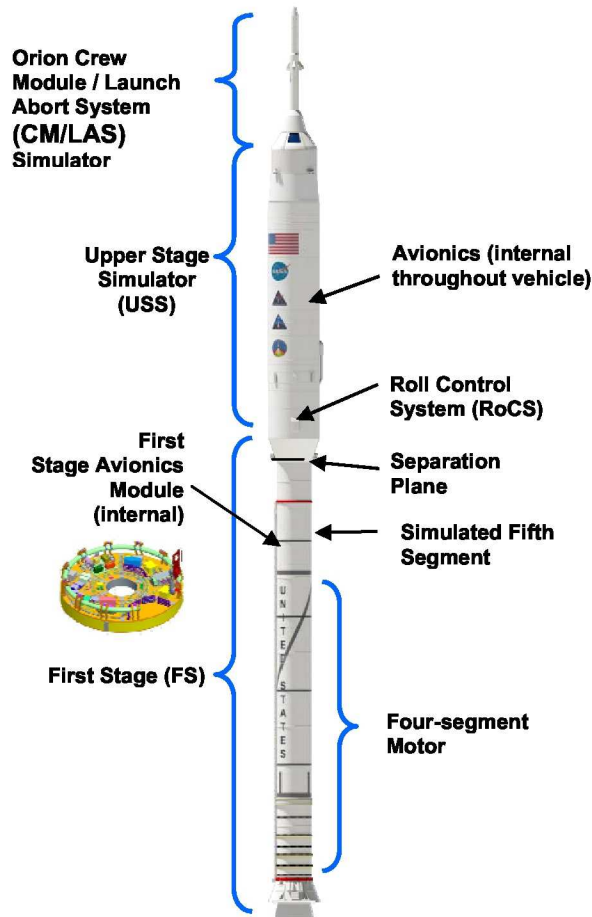


Figure 3. The Ares I-X provides an early opportunity to test the flight configuration of the Ares I crew launch vehicle.

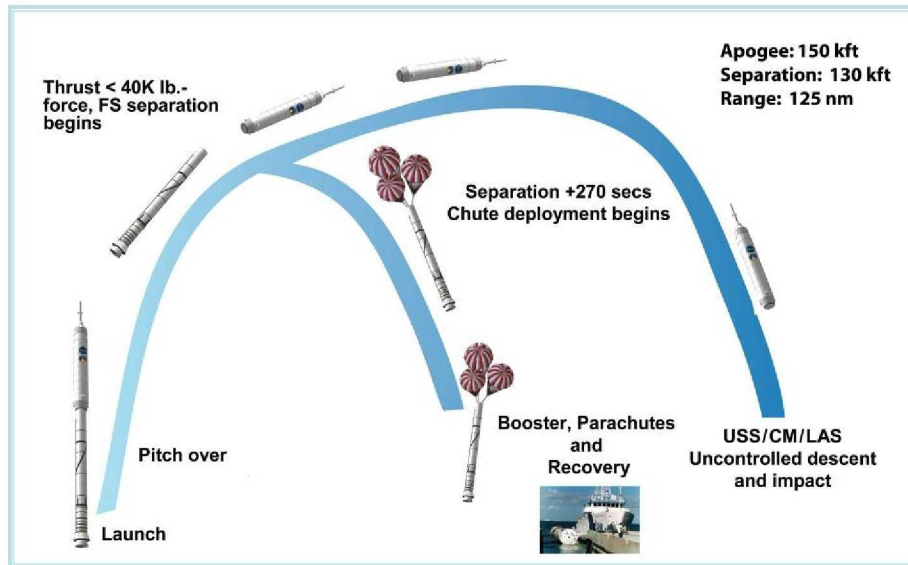


Figure 4. The Ares I-X flight profile closely resembles the uncrewed Saturn I flights of the 1960s.

In addition to the primary mission objectives previously listed, secondary test objectives for the flight include:

- Quantifying the effectiveness of the first stage separation motors.
- Characterizing the induced environments on the vehicle through all flight stages.
- Demonstrating a procedure for determining the vehicle's orientation vector for the flight control system.
- Demonstrating day-of-launch flight operations.
- Characterizing the induced loads on the vehicle on the launch pad.
- Assessing potential access locations in the VAB and on the pad.
- Validating the performance of the first stage umbilical system.

Ares I-X provides the first opportunity to test new assembly, integration, and test (AIT) functions at KSC. When vehicle elements began arriving at KSC in October 2008, some of them were moved to the Assembly and Refurbishment Facility (ARF), where developmental flight instrumentation (DFI) was integrated. The upper stage simulator (USS) segments were stacked in smaller "super stacks" in the VAB to support final assembly of the vehicle.

The vehicle will be launched from KSC Launch Complex (LC) 39B. Because of its Shuttle-ready state, LC 39B will need to be modified slightly to support Ares I-X until a full tear-down and redesign of the complex can begin after the Shuttle is retired. Additional vehicle interfaces and a sway damper will be added to the Mobile Launch Platform (MLP) to accommodate the much taller Ares I-X vehicle, which is 327 feet (99 m) tall, as opposed to the Shuttle, which stands 184 feet (56 m) tall. In addition, the Ares I-X USS will include a series of interior ladders and ring-shaped platforms to allow Ground Operations personnel to access the inside of the vehicle prior to launch. The ground support systems also include an environmental control system (ECS) to keep the avionics and ground staff cool prior to liftoff. The ECS will have a T-0 disconnect connection between the ground systems and the Flight Test Vehicle (FTV), which remains intact until the first stage ignition command (T-0) is issued.

MISSION STATUS

Ares I-X is moving closer to its scheduled launch in Summer 2009. With the individual elements and overall vehicle CDRs completed in Autumn 2008, much of the vehicle hardware has been delivered to KSC in Florida for integration, stacking, and launch.

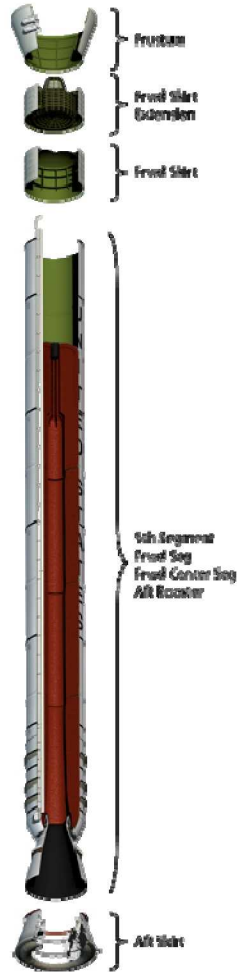


Figure 5. The first stage comprises most of the active vehicle elements for Ares I-X.

In addition to the DFI and Z-stripe, the first stage service tunnel was redesigned to extend the full length of the motor. These changes were made to accommodate a redesigned flight termination system (FTS), which was lengthened to comply with U.S. Air Force range safety guidelines.

The first stage aft skirt is also from the Space Shuttle inventory, but was modified to meet Ares needs. Eight booster deceleration motors are being added to the aft skirt to pull the first stage directly aft following separation. This maneuver will prevent future models of the Ares I first stage from contacting the J-2X engine bell. The aft skirt also includes two booster tumble motors, which cause the first stage to tumble in the yaw axis during descent, as well as ballast to ensure that the stage descends nozzle first and the parachute recovery system operates properly.

Most of the first stage hardware (Figures 7 and 8) is at KSC except the motor segments themselves, which will arrive via rail March 10.

FIRST STAGE

The Ares I-X first stage comprises a four-segment solid rocket motor with new forward structures added to house avionics and recovery systems, to match the length and shape of the Ares I first stage (Figure 5).

The motor segments, which have been in storage at ATK Space Systems' facility in Promontory, Utah, are having additional DFI and a "Z-stripe" design applied to the exterior. The DFI will provide critical measurements on environments and loads during the flight. The Z-stripe design will allow ground observers to better determine how much the vehicle rolls during flight (Figure 6).



Figure 6. Close-up image of motor segment with completed Z-stripe.



Figure 7. The frustum connects the first stage to the wider upper stage simulator.



Figure 8. The aft skirt will use a combination of existing Shuttle hardware and new hardware built specifically for Ares I-X.

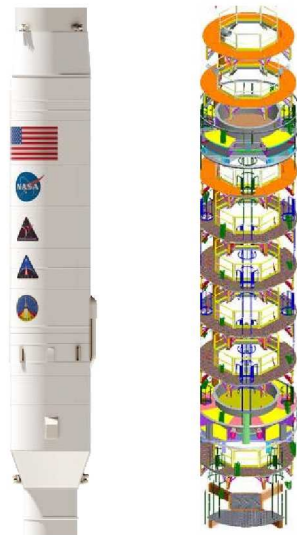


Figure 9. The complete upper stage (left) and plan view of interior platforms and ladders (right).

UPPER STAGE SIMULATOR

The upper stage simulator (USS) is an inert upper stage body designed to match the outer mold line (OML) of Ares I. Managed and fabricated at Glenn Research Center (GRC) in Cleveland, Ohio, the USS comprises 11 separate segments designed for ease of transport, assembly, and internal access (Figure 9). Each of these “tuna can” segments will house DFI, ladders, and platforms to ensure that ground staff can access the avionics. This unique arrangement was necessary because the launch tower at LC 39B, still configured to support the Space Shuttle, is not tall enough to access the upper reaches of Ares I-X. Ground staff will access the interior through a hatch located at the bottom-most, “interstage” segment.

The USS segments were delivered to KSC’s VAB in 2008 and are now being integrated into “super segments,” which will then be stacked into the fully integrated stage (Figure 10).



Figure 10. The upper stage simulator segments in the process of delivery (far left), unpacking (middle), and stacking (far right).



Figure 11. The launch abort system (LAS) simulator during assembly at Langley Research Center.

CREW MODULE / LAUNCH ABORT SYSTEM SIMULATOR

The simulator for the Orion crew module and launch abort system (CM/LAS), like the Upper Stage, ensures that Ares I-X matches the Ares I outer mold line (OML) as closely as possible. This precisely crafted simulator matches the OML (Figure 11) for an earlier design analysis cycle, but will include numerous sensors, which will provide critical information on thermal loads, aerodynamic buffeting, and acoustics during ascent.

The CM/LAS was designed and manufactured at Langley Research Center (LaRC) in Virginia and was shipped to KSC via C-5 cargo aircraft in January 2009 (Figure 12).



Figure 12. The CM/LAS simulator awaits shipping aboard its C-5 cargo aircraft.

13). The CM/LAS “super stack” is now being integrated and fitted with DFI at the VAB (Figure



Figure 13. CM/LAS awaiting assembly in the VAB.



Figure 14. The RoCS flight modules in the clean room at Teledyne Brown Engineering in Huntsville, Alabama.

ROLL CONTROL SYSTEM

The Ares I-X Roll Control System (RoCS) is being developed by Marshall Space Flight Center in Huntsville, Alabama (Figure 14). The RoCS performs two primary functions:

- Rolling the vehicle 90 degrees after liftoff to emulate the Ares I roll attitude at launch.
- Maintaining a constant roll attitude during ascent up to stage separation.



The RoCS, located in the lowest (“interstage”) segment of the Ares I-X upper stage simulator (USS), consists of two modules, each containing two thrusters capable of generating 1,200 pounds (5,337 newtons) of force (Figure 15). The RoCS modules, placed on opposite sides of the outer skin of the USS interstage segment, fire tangential to the skin and at right angles to the roll axis to provide a controlling roll torque. The RoCS will operate from just after the rocket clears the tower until just before first stage separation. As part of the USS, the RoCS is expected to break up after it falls into the Atlantic Ocean and will not be recovered.

The RoCS thrusters were harvested from decommissioned Peacekeeper missiles, which were to be dismantled by the U.S. Air Force as part of the second Strategic Arms Reduction Treaty (START II). The use of Peacekeeper parts for RoCS and Shuttle parts for the first stage was an effective means for NASA to reduce the cost and development time of this flight test, as the alternatives would have been to design and build new engines or use and discard reaction control thrusters needed for the Space Shuttle.

Figure 15. The arrow above indicates the location of one of the two RoCS modules.



Figure 16. RoCS flight unit undergoing fit checks at the VAB.

The flight units for the RoCS modules have been completed and shipped to the VAB in February 2009. The units also were fit-checked on the USS interstage segment in February (Figure 16). Cold-flow testing is expected to be completed on the RoCS test modules in March.

AVIONICS

The Ares I-X avionics are being developed by a NASA team at Marshall Space Flight Center that includes Jacobs Engineering and Lockheed Martin as a subcontractor. The vehicle avionics include four primary types of hardware:

- A fault tolerant inertial navigation unit (FTINU), developed from Atlas V avionics, which directs the rocket in flight.
- Space Shuttle-derived avionics (SDA), which controls the actions of the first stage, including the parachutes.
- A new ascent thrust vector controller (ATVC), which will translate between Atlas and Shuttle hardware.
- DFI, which will collect data on aerodynamic, vibration, thermal, thrust oscillation, and other forces during flight.

The Ground Command, Control, and Communication (GC3) system, installed in the mobile launch platform, will enable the Launch Control Center to monitor, interact with, and launch Ares I-X from LC 39B (Figure 17).

Ares I-X includes one completely new avionics box, the ATVC, which translates commands between the Atlas-based FTINU and the SDA in the thrust vector control system (Figure 18).



Figure 17. One of the Ground Command, Control, and Communication (GC3) racks, which will enable the Launch Control Center to communicate with and launch Ares I-X.



Figure 18. The ascent thrust vector controller (ATVC) communicates between Atlas V and Space Shuttle hardware to send steering commands to the first stage nozzle.



Figure 19. The Ares I-X avionics undergoing testing in the Systems Integration Laboratory.

The Ares I-X avionics systems were all integrated and tested in a systems integration laboratory (SIL) at a Lockheed Martin facility in Denver, Colorado (Figure 19). The SIL functions as a flight simulator for the computers, putting them through a variety of flight situations, much as a human pilot would be tested before flying a real aircraft. The SIL included interfaces (connections) to simulated or actual pieces of rocket hardware as well as proper lengths of wiring to ensure a realistic interaction between computers and hardware.

Avionics hardware is being installed in nearly every part of the Ares I-X flight test vehicle, from the crew module and launch abort system simulator to the aft skirt of the first stage. DFI sensors have been placed all along the CM/LAS, and along the inside and outside of the USS, and first stage.

Redundant rate gyroscope units (RRGUs) at the forward and aft ends of the rocket will continually monitor the rocket's location on the ground and in space. The RRGUs feed that information to the FTINU, the flight computer, which is mounted beneath the ballast in the middle of the USS to minimize movement.

The first stage avionics module (FSAM), located inside the empty fifth segment simulator, includes batteries, controls for the first stage rocket motor, parachute recovery system, and data storage. It will be recovered and its data downloaded and analyzed after the flight.

As of February 2009, over 90% of the cable harnesses, DFI, and Ground Support Equipment (GSE) had been delivered to KSC. This work has included modifying the Mobile Launch Platform (MLP) and installing the ground support avionics racks; as well as preparing Firing Room 1 at the Launch Control Center with new computers and launch control equipment.

The avionics system will provide critical engineering data that will be used for the final design of the Ares I crew launch vehicle's CDR in 2011.

GROUND SYSTEMS / OPERATIONS

The Ground Systems and Operations teams at KSC have been hard at work transitioning their activities from supporting primarily the Space Shuttle to supporting the Constellation Program...*while* the Space Shuttle is still operating. Despite this complex level of work, the Ground Systems and Ground Operations Teams have managed to design and fabricate the vehicle stabilization system (VSS) (Figure 20) and erect all three Lightning Protection Towers at LC 39B (Figure 21).

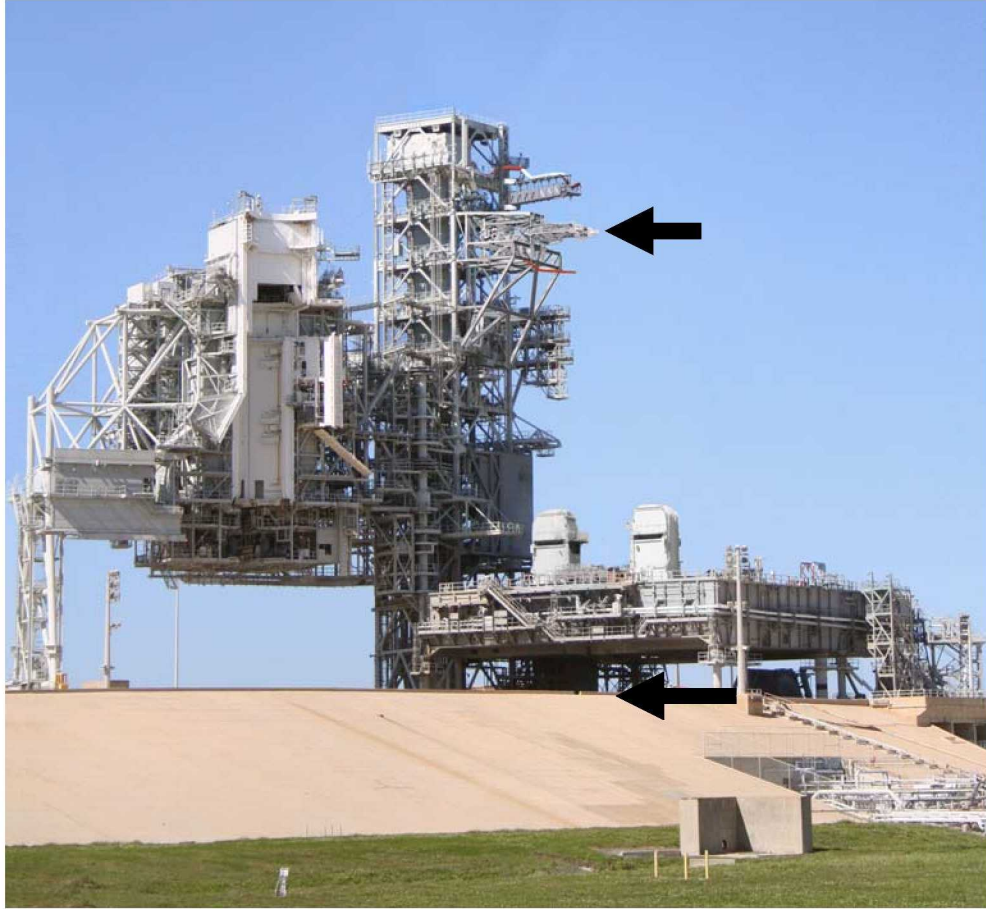


Figure 20. This arrow in the conceptual image shows the vehicle stabilization system as it will be placed on the Fixed Service Structure (FSS) at Launch Complex 39B.

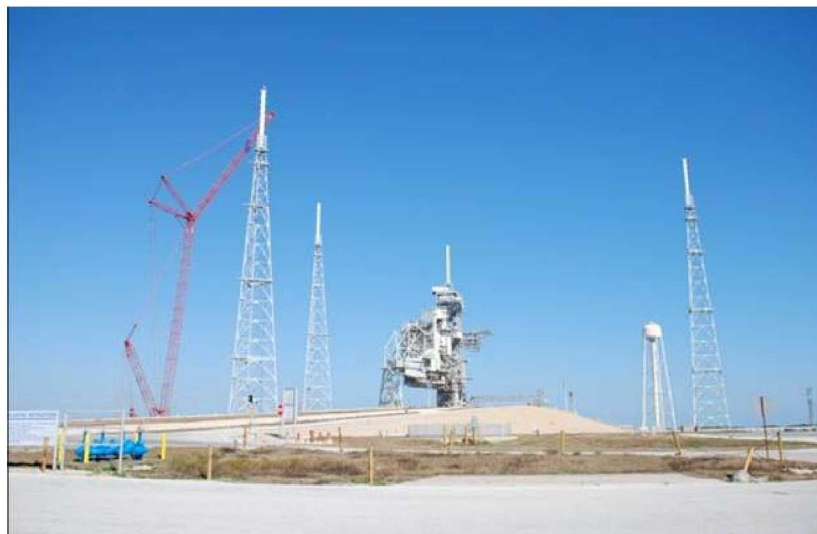


Figure 21. Ares I-X will be the first test use of the three lightning towers built for the Constellation Program.

MISSION SUMMARY

In the space of three years, NASA and its partners have designed, fabricated, and established the infrastructure for the test model of the Ares I crew launch vehicle. We have conducted multiple successful reviews; conducted major tests of critical elements; performed verification planning and started verification closeout for approximately 500 system and element level requirements; and developed key documentation for the flight. All that remains is to stack the vehicle, roll it out to LC 39B, and start the next era of American space exploration.



Ares I-X: On the Threshold of Exploration



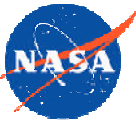
Stephan R. Davis, Deputy Mission Manager

April 14, 2009





Agenda



◆ Mission Background

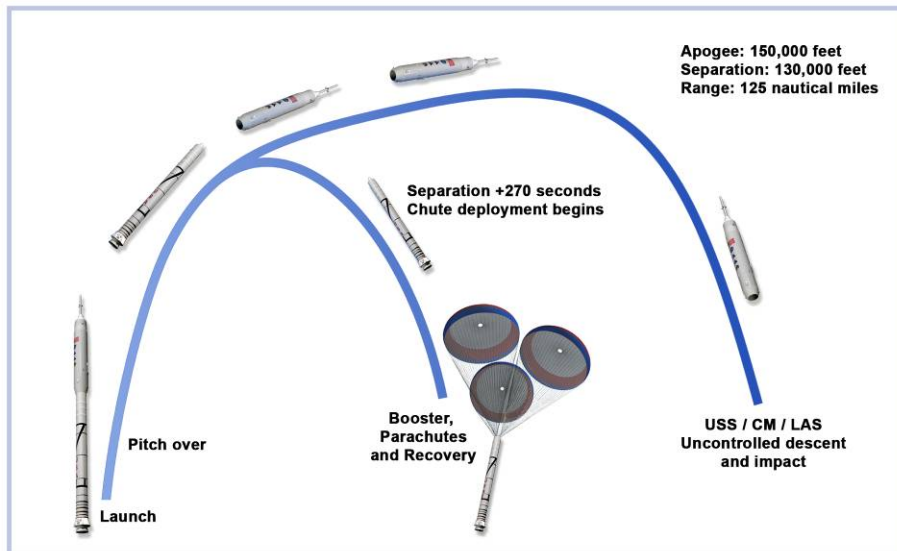
◆ Mission Status

- First Stage (FS)
- Upper Stage Simulator (USS)
- Crew Module / Launch Abort System Simulator (CM/LAS)
- Roll Control System (RoCS)
- Avionics
- Ground Systems / Ground Operations (GS/GO)

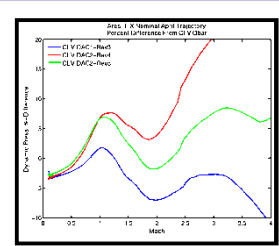
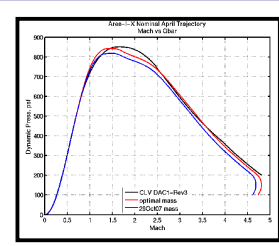
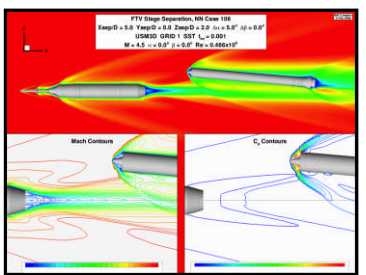
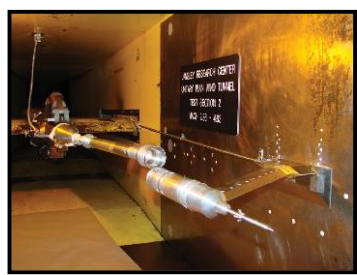
◆ Closing / Q&A



- ◆ U.S. developing next generation of crew and cargo launch vehicles for exploration beyond Earth orbit
- ◆ Ares I crew launch vehicle to carry astronauts to low Earth orbit in Orion crew exploration vehicle
- ◆ Ares V to carry Altair lunar lander and Earth departure stage for lunar missions
- ◆ Vehicle development includes development, verification, and orbital flight testing
- ◆ Ares I-X objectives:
 - Vehicle integration, assembly, and launch operations
 - Staging/separation
 - Roll and overall vehicle control
 - Aerodynamics and vehicle loads
 - First stage entry dynamics for recovery



- ◆ Test vehicle incorporates flight and mockup hardware
- ◆ Powered by a four-segment solid rocket motor from Shuttle inventory
- ◆ Flight profile approximates Ares I flight conditions through Mach 4.5 and 130,000 feet altitude
 - Includes transition through maximum dynamic pressure (“Max Q”)
- ◆ First opportunity to test new assembly, integration, and test (AIT) functions at KSC
- ◆ Launch from KSC Launch Complex (LC) 39B, which will be modified to support Ares I-X
- ◆ Vehicle 327 feet (99 meters) tall, 18 feet (5.5 meters) wide

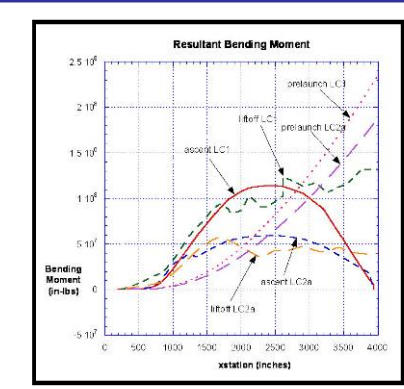
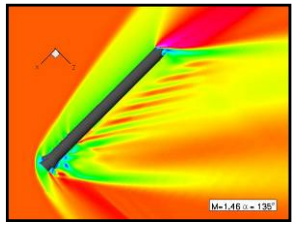


Trajectory

- Trajectories
- Malfunction Turn
- Baseline Databook
- Prelim Range Data Package

Aerodynamics

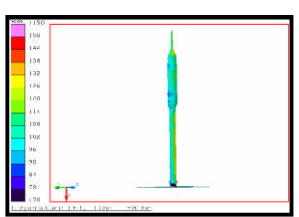
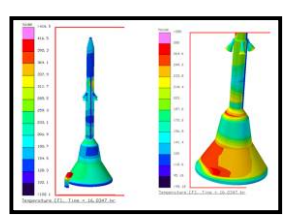
- Ascent Aero
- Transition Lift-off CFD
- Stage Separation CFD
- Rigid Buffet



Structures

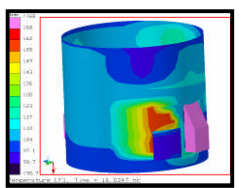
- Coupled Loads Cycle 1
- Cycle 2 Update
- Assess Rigid Buffet data

Integrated Design & Analysis

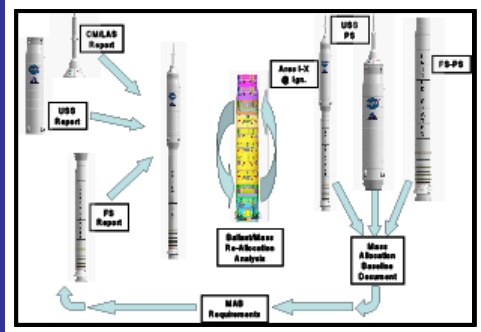


Thermal

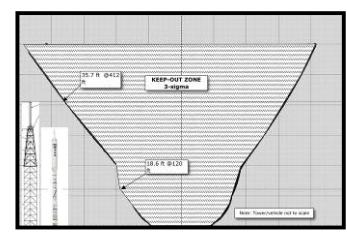
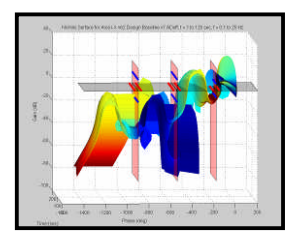
- Preliminary Stack
- Ascent on Pad
- Thermal Prediction Report & Databook



Integrated Mass Properties

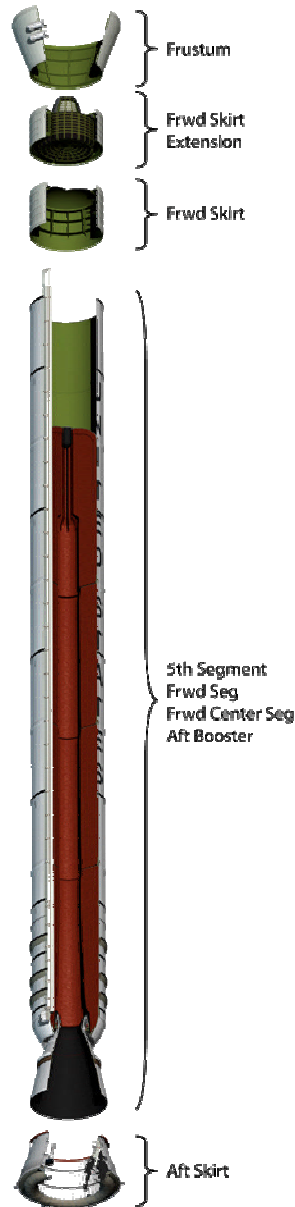


-Mass Allocation

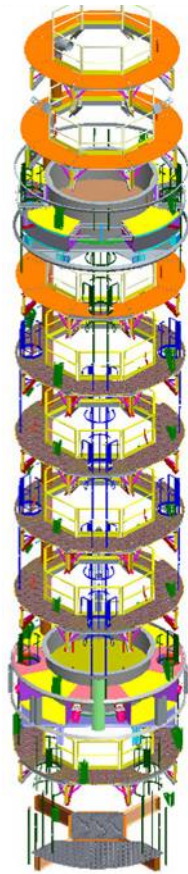


Guidance, Navigation & Control

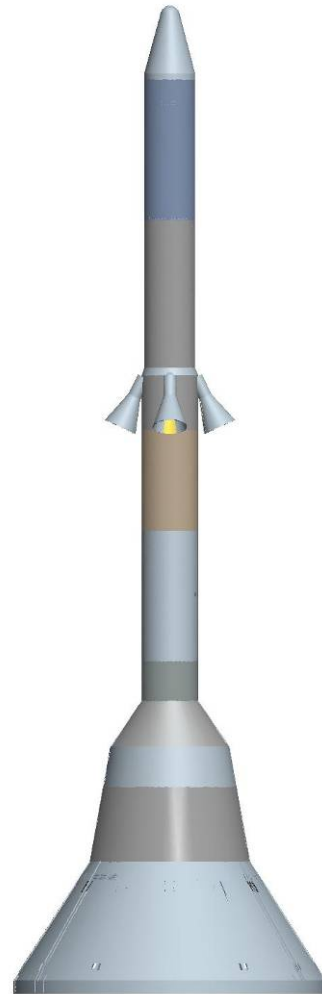
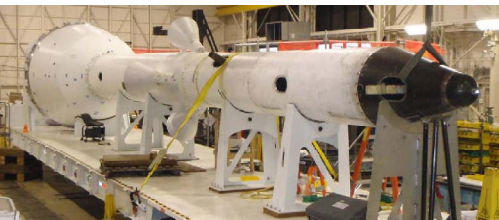
- Initial Flight Control Architecture
- Preliminary Stability Analysis
- Updated Drift Analysis
- Stage Separation Analysis



- ◆ Four-segment solid rocket motor with new forward structures
- ◆ Motor segments include additional development flight instrumentation (DFI) and a “Z-stripe” design for ground observations
- ◆ Service tunnel redesigned to cover full length of motor
- ◆ Aft skirt includes 8 booster deceleration motors (BDMs), two booster tumble motors (BTMs), ballast, DFI, and redundant rate gyro units (RRGUs)
- ◆ Forward structures delivered to Kennedy Space Center (KSC) in February; motor segments in March
- ◆ Stacking to begin in Spring 2009

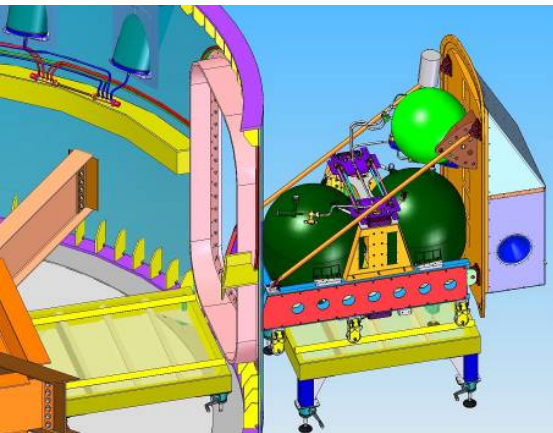


- ◆ Inert upper stage body designed to match the outer mold line (OML) of Ares I
- ◆ Designed and built at Glenn Research Center (GRC)
- ◆ Comprises 11 separate segments designed for ease of transport, assembly, and internal access
- ◆ Ladders and platforms ensure ground staff can access avionics
- ◆ Entry to interior through hatch at bottom-most, “interstage” segment
- ◆ Delivered to KSC’s VAB in late 2008
- ◆ Stacked in “super segments”
- ◆ Final stacking to occur mid-2009

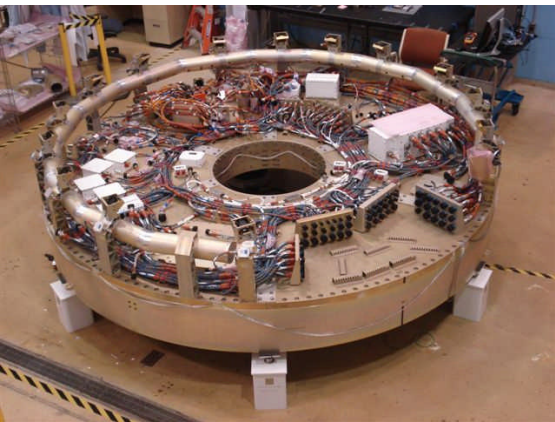
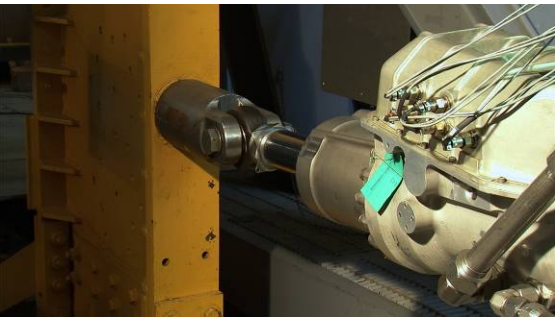


- ◆ Matches the Ares I OML as closely as possible
- ◆ Built at Langley Research Center
- ◆ Includes numerous sensors to collect critical information on:
 - Thermal loads
 - Aerodynamic buffeting
 - Acoustics during ascent
 - Acceleration
- ◆ Shipped to KSC via C-5 January 2009
- ◆ To be stacked atop vehicle Summer 2009

Roll Control System (RoCS)

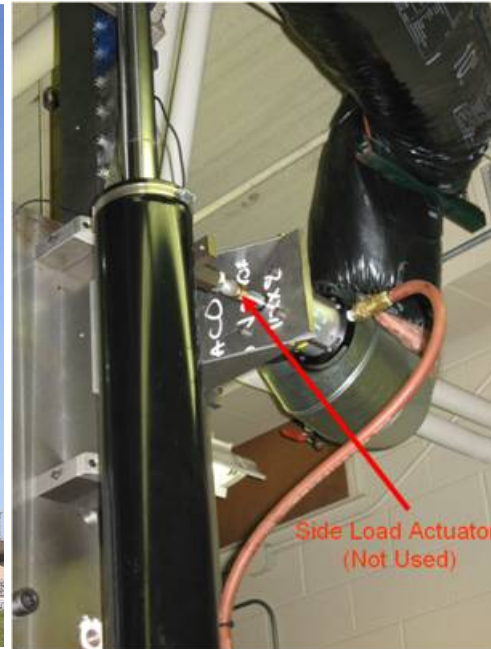


- ◆ Rolls the vehicle 90 degrees after liftoff to emulate the Ares I roll attitude at launch
- ◆ Maintains a constant roll attitude during ascent up to stage separation
- ◆ Hypergolic propellants (Nitrogen Tetroxide/Monomethyl Hydrazine), 1,200-pounds thrust
- ◆ Harvested from decommissioned Peacekeeper missiles
- ◆ Flight units shipped to VAB in February 2009
- ◆ Fit check completed March 2009
- ◆ Final installation Summer 2009



- ◆ Primary components:
 - Fault tolerant inertial navigation unit (FTINU), developed from Atlas V avionics, to direct rocket in flight
 - Space Shuttle-derived avionics (SDA), to control the first stage, including parachutes
 - New ascent thrust vector controller (ATVC), translate between Atlas and Shuttle hardware
 - DFI to collect data on aerodynamic, vibration, thermal, thrust oscillation, and other forces during flight
 - Ground Command, Control, and Communication (GC3) system, installed in the mobile launch platform, to monitor, interact with launch vehicle

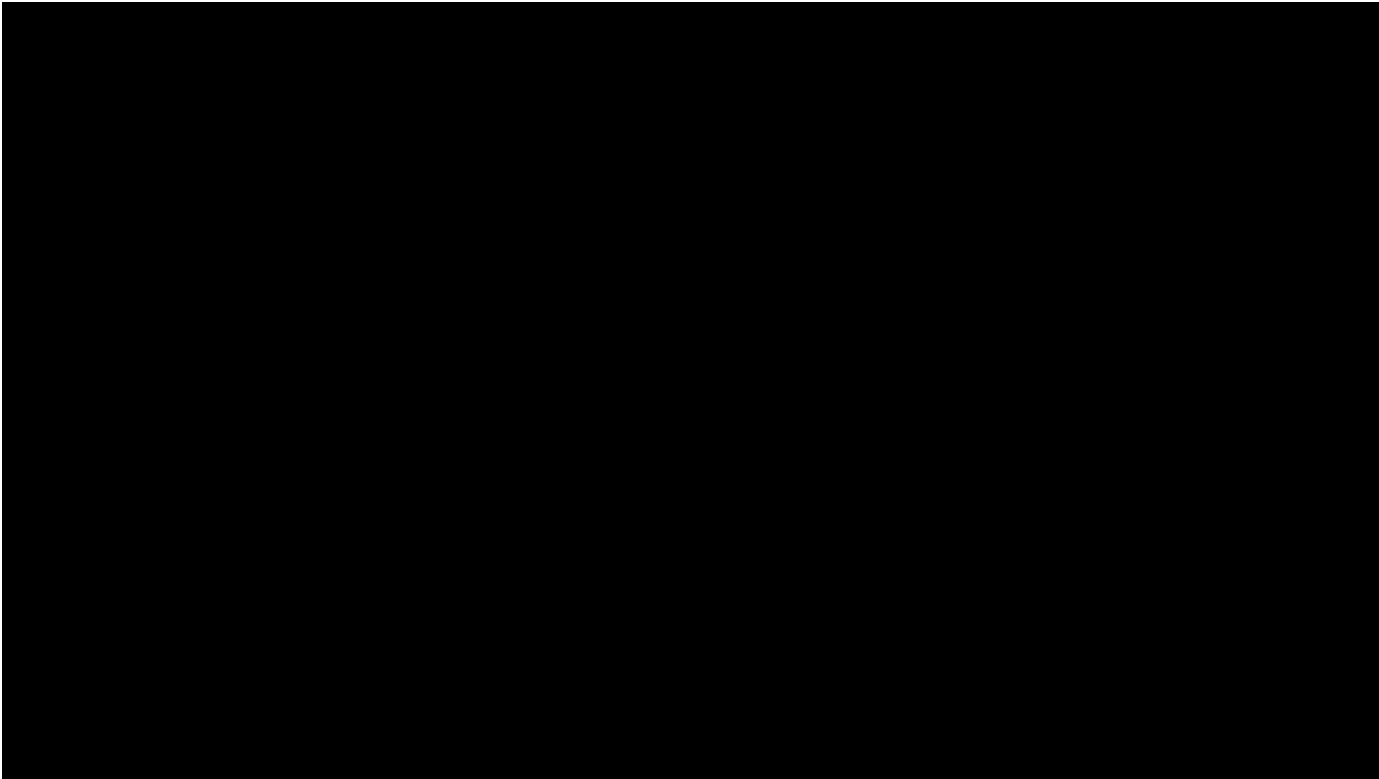
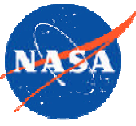
- ◆ Hardware integration and testing
Autumn 2008 – Summer 2009



- ◆ Modifying VAB and LC 39B to accommodate Ares I-X vehicle operations
- ◆ Vehicle stabilization system to keep vehicle stable on pad
- ◆ Built new lightning towers to accommodate taller vehicle
- ◆ Fabricating environmental control systems for ground crews and avionics
- ◆ Updated computers in Launch Control Center Firing Room
- ◆ Sharing resources with ongoing Space Shuttle operations
- ◆ Launch due Summer 2009

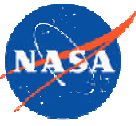


Coming Attractions





Closing



- ◆ In three years, NASA and its partners have designed, fabricated, and established the infrastructure for Ares I-X
- ◆ We have performed:
 - **Multiple successful reviews**
 - **Major tests of critical elements**
 - **Verification planning and started verification closeout for approximately 500 system and element level requirements;**
- ◆ All that remains is to stack the vehicle, roll it out, and start the next era of American space exploration

Questions?